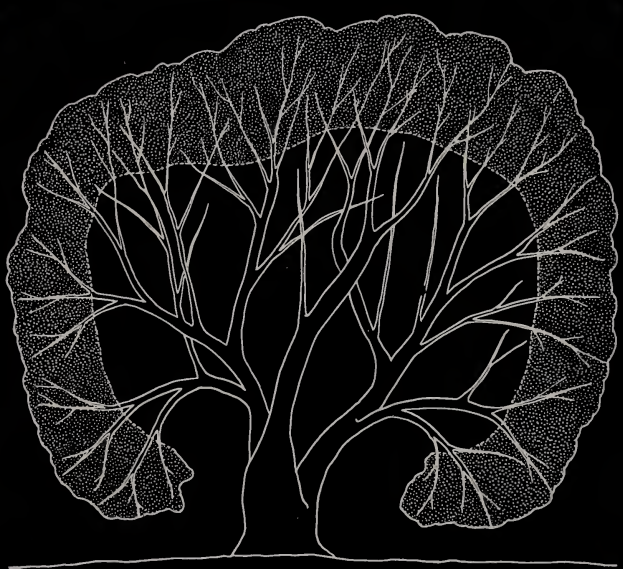
Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

PRUNING OLIVES
in California



". . . . Highest yields are likely if this natural fruit-bearing area is kept as large as possible . . . . ."

H. T. HARTMANN • KARL OPITZ • R. M. HOFFMAN

CALIFORNIA AGRICULTURAL EXPERIMENT STATION

BULLETIN 771

Research has shown that . . .

In nonbearing olive trees, any pruning retards vegetative growth, but some training is necessary to develop a strong trunk and a well-branched primary scaffold system. Light summer pruning during the first several years will achieve that purpose.

In bearing olive trees, pruning reduces yields in proportion to the removal of fruit-bearing wood. Limit all pruning to cutting with some definite objective:

To ease harvesting and spraying, to reduce disease and insect damage:

Remove dead wood, suckers, and watersprouts,

Thin out dense, brushy growth in the fruiting area, and

Remove excess scaffold branches.

To keep trees down to reasonable heights:

Head back the upright and lateral branches,

Cut back large limbs of trees grown too high.

Bearing olive trees may be pruned at any time of the year. In orchards infected with olive knot, prune in the summer to reduce spreading of the bacteria.

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MAY, 1960

Some pruning may help

Olive growers in California have used many different methods in pruning their trees, both bearing and nonbearing. Such methods range from no pruning to very severe pruning. No specific procedures for training young trees are generally followed.

This bulletin reports research on:

Methods for training young trees to induce early bearing and, at the same time, develop a mechanically strong tree framework.

Methods of pruning bearing trees to induce maximum yields over a period of years consistent with large fruits, ease of harvesting, and insect and disease control.

The practical findings of the research are summarized on pages 13 and 29.

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PRUNING OLIVES IN CALIFORNIA*

H. T. HARTMANN • KARL OPITZ • R. M. HOFFMAN

REVIEW OF LITERATURE

California. Bioletti (1922)† in a pruning study of young Mission olive trees at Davis, California, concluded that pruning retards the growth of olive trees, especially when they are young. He estimated that the excessive pruning sometimes practiced on young trees retards their development as much as 90 per cent. He found that severe pruning of young trees delayed the onset of bearing by one year in comparison with unpruned trees.

Jacob (1934) studying young Mission, Sevillano, Ascolano, and Manzanillo olive trees at Davis, California, also found the same growth-depressing effect from pruning for the first three varieties. A single severe pruning of trees left unpruned until they were five years old, had about the same depressing effect as five light annual prunings. For Manzanillo, however, trees lightly pruned annually for five years developed faster than those left unpruned. Trees left unpruned until they were five years old produced heavier crops in the fifth season than did trees lightly pruned annually. The severely pruned trees did not produce a crop of commercial importance during the seven years records were taken.

In observing responses of young olive trees to pruning, Opitz, in unpublished data, recommends the following procedure for training such trees in Tulare County:

Suppress all lateral growth lower than 12 to 24 inches from the ground by frequent pinching in the summer to develop a straight, unbranched trunk.

Where necessary, support the growing tree with a 5- to 6-foot grape stake.

Remove or shorten branches that might be injured or destroyed by cultivation.

Allow all other growth to develop as it may.

Following the first crop—or during the first fruiting season if the crop is heavy—light annual pruning is suggested. This consists of removing shaded, weak, inside limbs and cutting back or suppressing crossing and interfering branches. Allow watersprouts to develop if they are growing from a position that will not interfere with the development of a well-balanced tree. Pinch back and eventually remove unwanted watersprouts. Encourage three to five framework branches to develop at well-spaced intervals beginning 12 to 24 inches from the ground.

Pruning studies of bearing olive trees at Corning, California, were reported by Merrill and Condit (1928). Twelve-year-old Sevillano trees received annually minimum, medium, and heavy pruning. Annual yields per tree over a three-year period were: 70 pounds for the minimum pruning, 67 pounds for the medium pruning, and 35 pounds for the heavy pruning. In regard to fruit size over the three-year period, the heavy pruning re-

* Submitted for publication May, 1959.

† See "Literature Cited" for citations referred to in the text by author and date.

sulted in an average of 51 per cent "colossal" and "super-colossal" olives, medium pruning in 50 per cent, and minimum pruning in 39 per cent of these sizes. However, in considering the *pounds* of olives of these sizes produced, the heavy pruning yielded an average of 14.2 pounds per tree per year, the medium pruning, 25.3 pounds, and the minimum pruning, 20.1 pounds. In other words, the *percentage* of the larger olives was higher in the heavily pruned trees, but due to the low total yield, the number of *pounds* was much less. Merrill and Condit concluded from this experiment that heavy pruning reduced the total yield as well as the yield of the larger-sized olives.

Moore (1945) reported upon the results of a four-year pruning experiment with mature Manzanillo olive trees at Lindsay, California. Starting with large trees that had received no pruning for the previous 12 years, three pruning methods were used: (1) trees pruned every year in February, (2) trees pruned at two-year intervals in July, and (3) no pruning. The results are summarized in table 1.

Conclusions drawn from this study were that the yields were reduced in the pruned trees about in proportion to the amount of pruning, and that fruit size was not appreciably affected by pruning.

Spain. Although the pruning practices vary from one district to another, from the standpoint of maximum production the amount of pruning is excessive by California standards. The severe pruning in the unirrigated Spanish groves may be justified, however, because water loss from the tree must be reduced during periods of drought and because heavy pruning may be needed to stimulate new shoot growth since little nitrogenous fertilizers are used. Fungicidal sprays are rarely used, and the heavy pruning probably helps control such diseases as peacock spot (*Cycloconium oleaginum*) and *Macrophoma*. In Spain it is believed that fruit sizes are improved by heavy pruning (Opitz, 1956).

Pruning tends to be lighter in the province of Granada than in Jaen and Cordoba. Trees in certain regions of Granada do not receive any pruning; such trees have made exceptionally large growth and have yielded heavily (Diaz,

Table 1. Results of four-year pruning experiment in Tulare County. Mature Manzanillo olive trees. Data of Moore (1945).

	Trees pruned annually	Trees pruned twice in four years	Trees not pruned
Average annual yield per tree (lbs)	227.3	232.0	254.2
Average annual yield per acre (lbs) (based on 30 × 30 foot spacing)	11,001	11,229	12,303
Average per cent of fruit in top three size grades	52.6	46.0	52.0
Average per cent of fruit "petites" and "culls"	17.0	23.7	21.0
Comparison of average values of crop per ton, based on 1941 grade prices (dollars)	131.25	121.25	129.50
Gross value of crop per acre per year	721.94	680.75	796.62
Approximate total time of pruning labor per tree during the four-year period (hrs)	4¼	3¼	0
Approximate average time of pruning labor per acre per year on basis of 48.4 trees per acre (hrs)	51.4	39.3	0
Reduction in crop value per acre per year due to pruning (dollars)	74.68	115.87	0

1954). However, in much of the larger production areas in Spain the trees are pruned annually or biennially.

Italy (Opitz, 1957). Many olive orchards in Italy receive little or no pruning, and the trees become very large; on the other hand, in some areas of Italy, probably the most drastic pruning procedures in the world are used. Various rather detailed pruning systems have been developed to limit tree size, regulate bearing, and to compensate for lack of rainfall.

Specific recommendations (Savastano, 1934) advise that newly-planted trees not yet in bearing should be pruned very lightly, while young trees which have just started bearing should also be pruned lightly, just enough to shape the tree, aiming at a strong, easily accessible tree of large framework. The full grown tree should be pruned moderately each year, enough to insure adequate light for the remaining branches and to correct faults in growth. When the trees are old or have ceased to bear well, they must be pruned more heavily. Old, useless branches should be eliminated, with young, newly-formed shoots taking their place. This should be accompanied by abundant organic and inorganic fertilization. Pruning alone cannot replace fertilization.

France (Bonnet, 1944). Recommendations for pruning bearing olive trees state that the pruning should be done annually, making small cuts rather than resorting to heavier pruning at longer intervals. Suckers and dead or weak branches should be removed and long-growing branches should be shortened to induce growth of new shoots near the main scaffold branches.

Algeria (Rebour, 1944). The vigor of the mature tree is the basis for the pruning recommendations. Weakly-growing, nonfruitful trees receive a fairly strong pruning so as to invigorate the remaining branches. With trees of average vigor and normal fruitfulness, only a moderate pruning is recommended. For unfruitful, excessively vigorous trees, light or no pruning is advised. A light type of pruning is recommended for trees grown under irrigation and in soils that are rich and well fertilized. Under non-irrigated conditions it is pointed out that after a heavy crop has set, a heavy pruning may have to be done to allow the trees to conform to the limited water supply in the soil.

Morocco (Briand *et al.*, 1949). It is advised that in no case should pruning be excessive; this is especially true with trees coming into bearing, as it will retard fruit production. In pruning trees to obtain fruitfulness, it should be remembered that the olive produces most of its fruit on wood which grew the previous year. Generally, this wood produces fruit only once and after that it is used to support future branches that will bear fruit. In addition, the most fruitful branches are those of average vigor which are horizontal or hanging down. The upright growing branches tend to remain vegetative. Sucker and water-sprout growth also is unproductive and should be removed.

The quantity of fruit-bearing wood to be left on the tree depends upon the vigor of the tree. The higher the fertility of the soil, the greater the fertilization given, and the more irrigation water available, the less severe the pruning will need to be. It is recommended that the pruning be done annually.

Greece (Anagnostopoulos, 1953). Annual pruning is considered necessary to reduce the tendency toward alternate bearing. Winter pruning is recommended, coinciding with harvest, to remove shoots most heavily loaded with fruit. The most fruitful shoots are believed to be those making an annual growth of about 12 inches with internode

lengths of about ¼ to 1¼ inches. This desirable type of fruiting shoot can be obtained by adjusting the amount of pruning. Summer pruning may be used to reduce transpiration of unirrigated trees in years of excessive drought.

EXPERIMENTS IN PRUNING AND TRAINING YOUNG OLIVE TREES

Methods

Objectives in these studies were the development of methods of training newly-planted olives in such a way as to produce trees with a strong, well-shaped trunk and primary scaffold system and, at the same time, not appreciably delaying growth and the onset of bearing.

The earlier studies of Bioletti (1922) and Jacob (1934) showed generally that *any* pruning of young olive trees tended to retard growth and delay bearing, and that such effects are more pronounced as the pruning becomes more severe. Summer pruning, therefore, seemed to offer the most promise as a method of training the trees by eliminating unwanted shoots and, at the same time, removing a minimum amount of wood. All pruning of the young trees in this study was therefore done as summer pruning; removed were small shoots which would have developed into undesirable branches.

Trees of the Mission variety, propagated as rooted cuttings, were used. The nursery trees, as straight whips, were planted at the California Agricultural Experiment Station Orchard, Winters, in April, 1949, spaced 35 × 35 feet apart, in a very deep and fertile Yolo silt loam. Temporary trees were planted in the centers of the 35-foot squares, but the spacing was sufficient so that these trees did not interfere with the experiment. Clean cultivation was maintained throughout the experiment, with three to five flood-type irrigations given each year during the summer months. Watering was more frequent during the first three years, being applied in small flood basins around each tree. No fertilizers were applied throughout the course of these experiments since leaf analyses showed the trees to be adequately supplied with mineral nutrients.

Three treatments were used initially, with 11 tree replicates—two summer-pruned (A and B) and one unpruned (D). The training objective for the two-pruned plots was to develop three to five well-placed primary scaffold branches arising from the main trunk, spaced one to three feet from the ground level, well-separated up and down the trunk, and directed outward equally around the tree. In treatment B (see figure 1) a stake was driven into the ground beside the tree with sticks nailed to the stake laterally upward, to which the primary scaffold branches were tied so as to direct them to the desired position. In treatment A this was not done.

In an additional treatment (treatment C), no pruning was given any of the trees until they came into bearing (after the fourth growing season). At that time these trees were pruned rather drastically in an attempt to train them in one operation by removing excess primary scaffold branches, with the remaining branches constituting the permanent primary scaffold system (see figure 2).

Table 2 shows the dates of pruning, the time consumed, and the dry weight of prunings removed for each of the treatments during the first five years, at which time the primary scaffold system was considered to be permanently established.

Fig. 1. Three methods of pruning young Mission olive trees: Treatment A (above, left): Trees trained to from three to five primary scaffold branches by summer pruning. Treatment B (above, right): Same as treatment A but primary scaffolds tied to stakes to direct growth. Treatment D (page 9 to the right): Trees unpruned. Photos taken at the end of second growing season (1950).

Table 2. A comparison of methods of training young olive trees. Time consumed per tree in pruning, and dry weight of prunings removed per tree during the first five years. Mission olives. Winters, California. Trees planted April, 1949.

Date of pruning	Trees trained by annual summer pruning (treatments A and B)		Trees untrained until fourth year then trained by heavy pruning (treatment C)		Unpruned (treatment D)	
	Time, minutes	Weight of prunings, lbs	Time, minutes	Weight of prunings, lbs	Time, minutes	Weight of prunings lbs
August, 1949	1	0.03	0	0.0	0	0.0
April, 1950	1	0.04	0	0.0	0	0.0
August, 1950	1	0.15	0	0.0	0	0.0
June, 1951	1	0.28	0	0.0	0	0.0
August, 1952	1	0.78	0	0.0	0	0.0
April, 1953	..	..	11	25.2	0	0.0
Totals	5	1.28	11	25.2	0	0.0

Results

Figure 3 shows the difference in appearance of the primary scaffold system after four years' growth between trees trained by summer pruning (treatments A and B) and unpruned trees (treatment D).

Table 3 gives trunk cross section area measurements over a 10-year period of the trees maintained under the different types of training. Table 4 gives the fruit yields per tree during a six-year period, from 1953 to 1958, inclusive.

Vegetative growth of the trees was retarded even by summer pruning. In 1958, at the end of the study, trees receiving only a light summer pruning during their first four years of growth averaged 1154 sq. cm. in trunk cross section area while trees trained by receiving one heavy pruning after four years of growth averaged 1829 sq. cm. and entirely unpruned trees averaged 1867 sq. cm.

Large yield differences among the various pruning treatments did not occur.

Fig. 2. Below: Methods used to develop a primary scaffold system in previously unpruned trees by cutting out unwanted scaffolds after trees started bearing (Treatment C). Top row: Typical trees before pruning. Bottom row: Same trees following pruning. After four years' growth.

Table 3. Effect of three methods of pruning on vegetative growth as measured by trunk cross section area. Mission olives. Winters, California. Trees planted April, 1949.

Date	Trunk cross section area Measurements made at end of growing season			Differences required for significance	
	Trained by summer pruning during first four years (treatments A & B) sq. cm.	Trees trained by heavy pruning after four seasons' growth (treatment C) sq. cm.	Unpruned (treatment D) sq. cm.	at 5 per cent level	at 1 per cent level
1949	1	....	1		
1950	3	....	6		
1951	18	....	38		
1952	69	198	222		
1954	278	416	468		
1957	854	1297	1456		
1958	1154	1829	1867	343	480

Fig. 3. Comparison of primary scaffold system of typical trees trained by summer pruning (Treatments A and B, top row) with unpruned trees (Treatment D, bottom row). After four years' growth.

Table 4. Yields per tree from the fifth to tenth year, inclusive, of Mission olive trees trained by four different methods. Winters, California. Trees planted April, 1949.

Year	Treatment A: Summer pruned during first four years. Lateral branches not staked	Treatment B: Summer pruned during first four years. Lateral branches tied to stakes	Treatment C: Untrained until fourth year (1952), then trained by heavy pruning	Treatment D: Unpruned	Difference required for significance	
					at 5 per cent level	at 1 per cent level
	pounds					
1953	17	27	33	29	17	23
1954	85	99	115	130	45	62
1955	61	79	74	88	11	32
1956	236	266	262	287	27	78
1957	174	214	138	110	22	66
1958	307	338	302	231	79	109
Total six-year yield per tree	880	1023	924	875		

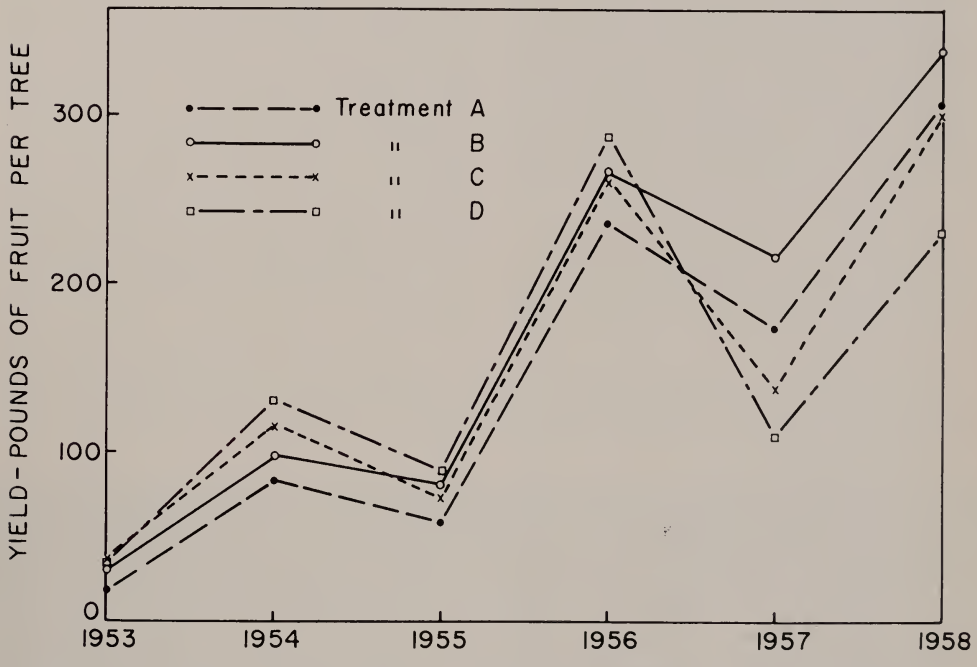


Fig. 4. Comparison of annual yields for trees receiving different pruning treatments. A—Trees trained by annual summer pruning during the first four years. B—Same as A but primary scaffold branches tied to stakes to direct growth. C—Trees unpruned until the end of the fourth season's growth, then trained by removal of excess primary scaffold branches. D—Trees unpruned. Mission olives, Winters, California.

As shown in figure 4, the unpruned trees in the earlier years of the experiment out-yielded the pruned trees, but not to a great extent. In the latter portion of the period under study the pruned trees, even though smaller, according to trunk diameter measurements, outyielded the unpruned trees. Thus, in comparing the total yields over the six-year period, differences among the four treatments were not large.

Discussion

Any severe pruning of young olive trees will retard growth and delay the onset of bearing; how, then, can a tree be developed with a strong, well-shaped primary scaffold branch system while holding pruning to a minimum? Such pruning seemed most reasonably done as summer pruning; removing unwanted branches when they were only several inches long would be the least severe type of pruning that could be accomplished. However, in this study even such light pruning, practiced only during the first four years of growth, retarded tree growth in comparison with unpruned trees. Such growth differences were still evident after the tenth year.

One purpose of this type of minimum pruning was accomplished, however; the summer-pruned trees had a strong, well-shaped system of primary scaffold branches, as shown in figures 3 and 5. None of the summer-pruned trees blew over in winds or had branches break off at the ground level. In the unpruned trees, however, this was an important detrimental factor. Forty per cent of the unpruned trees in this test either blew over in winds or had one or more of the main branches break off at the ground. As the main branches of unpruned trees enlarged (as shown in the lower part of figure 3), they pushed against each other and had a tendency to break off in strong winds.

There were no striking differences between the behavior of summer-pruned trees which had scaffold branches tied to lateral stakes, and that of summer-pruned trees with branches not so tied. In three of the six years yield records were taken (1955, 1956, and 1957), trees with lateral branches tied had significantly higher yields at the five per cent level than trees with branches not tied. This increased yield may possibly be due to the better spacing of the scaffold branches with less crowding of the fruiting area as the trees became older. It is rather doubtful, however, that enough benefit would accrue from this rather time-consuming procedure to justify its use, especially in developing a large orchard.

Fig. 5. Appearance of typical trees trained by three different methods of pruning after 10 years of growth. Left: Tree trained by summer pruning during first three years. Center: Tree unpruned during first four years then trained by removing unnecessary primary scaffold branches. Right: Unpruned tree.

The unpruned trees outyielded the pruned trees in the first four years of bearing; this trend, however, was reversed during the latter years of the study. The unpruned trees, although larger (as measured by trunk diameter) than pruned trees, had such a dense top growth due to the relatively large number of primary scaffold branches, that excessive shading soon occurred; much of the top growth became unfruitful, and developed a considerable amount of dead twigs. This may explain the decreased yields of the unpruned trees toward the end of the study in comparison with the pruned trees which, with fewer scaffold branches, would not develop an overcrowded condition in the top of the tree as soon as the unpruned trees.

The method of training given in treatment C, in which the trees were allowed to develop unpruned until after their fourth growing season and then were given a fairly heavy pruning to shape the tree, gave better results than expected. The inhibition of growth due to early pruning was not encountered and the heavy pruning at the onset of bearing was not especially detrimental, either in future vegetative growth or in yields. Yields may have remained high, in spite of the removal of a considerable portion of the top fruiting surface, because of two reasons: (1) thinning out of the top avoided the dense, overly-crowded condition which occurred in the unpruned trees, and led to increased fruitfulness; and (2) an actual stimulation of fruit setting due to a decrease in the top-root ratio. This latter situation has often been noted previously in top-grafting olive trees, where a nurse branch is retained. Removal of all the fruiting top of the tree except the nurse branch usually results in a very heavy fruit set on the nurse branch, due probably to the greatly increased supply of moisture and available nutrients from the entire root system to the one nurse branch.

The nature of the trunk and primary scaffold system in treatment C, after the heavy pruning, was far from satisfactory, however, as shown in figures 2 and 5. The several main branches coming directly from the ground in later years, after enlargement, will tend to push against each other and to break off in winds.

Conclusions

1. Any pruning of young, nonbearing, olive trees will retard vegetative growth in comparison with unpruned trees. Even the very minimum type of summer pruning, as practiced in this study, reduced growth.

2. Some training of the young trees during the first few years is necessary if a strong trunk and a well-branched primary scaffold system is to be developed. An unpruned olive tree develops as a bush rather than a tree and the primary scaffold branches thus develop as enlargements of the suckers arising at ground level. As the tree becomes older these main branches enlarge, push against each other, and tend to break off, either in winds or from a heavy fruit load.

3. The system of allowing the tree to grow unpruned until it comes into bearing, then developing the primary scaffolds by removing the excess branches seems suitable as far as rapid tree growth and fruitfulness is concerned but it is unlikely to result in a satisfactory permanent trunk and scaffold system.

4. The system of light summer pruning during the first several years of tree growth resulted in an entirely satisfactory trunk and primary scaffold system. While even this minimum pruning reduced tree growth as well as yields during the first four years of fruiting, such trees later yielded more heavily than the unpruned trees.

Three general methods of pruning bearing trees have been practiced in California:

Heavy pruning, in varying degrees of severity, given annually or more often, every other year, or every third or fourth year. The proponents of this method believe that heavy pruning will secure larger fruit size, heavier fruit sets, and easier harvesting and pest control.

Light pruning, consisting only in the removal of dead wood, suckers, and watersprouts, done annually or once in several years.

No pruning except perhaps the removal of broken limbs and suckers. Advocates of the latter two methods believe that yields are reduced by heavier pruning without sufficient increase in fruit size to offset the yield reduction.

To determine which of these three types of pruning would result in the most profitable crops over a period of years while maintaining the trees in a healthy condition, two experimental plots receiving such treatments were established in 1946 in irrigated orchards—one near Corning in Tehama County, and one near Oroville in Butte County. In addition, five plots were established in Tulare County in 1949, also comparing mature trees receiving heavy, light, and no pruning.

The general plan of the Corning and Oroville experiments was to use a uniform block of trees and prune one third of the trees severely each year, one third moderately, while one third received no pruning. These tests were conducted for six years, although the severe pruning treatment was discontinued after the fourth year. Individual tree yields were recorded each year and commercial size grades of the fruit from trees receiving the different types of pruning were obtained. By using these data, together with the price paid growers per pound of fruit in the various size grades, the gross returns per tree could be calculated.

Corning experiments

This plot was established at the Maywood orchard, about 5 miles southwest of Corning on Tehama gravelly loam soil. Sevillano trees, about 50 years old planted 30×30 feet apart, were used. This orchard had an average annual production of 2.6 tons per acre from 1944 to 1949. For some years prior to the establishment of this experiment the trees had received a rather light annual pruning.

The plot of severely-pruned trees consisted of 21 trees running north and south through the entire orchard. The moderately-pruned plot contained 27 trees in a row adjacent to the severely-pruned trees. There were 27 trees in the

TYPICAL EXPER

Fig. 6. Tree in the "severely-pruned" plot.

unpruned plot and these were in a row adjacent to the moderately-pruned trees.

The trees were pruned in late winter or early spring as shown in figures 6, 7, and 8. The approximate amount of wood removed per tree is shown as well as the appearance of the trees after pruning. While the severely pruned tree in figure 6 is not cut back as heavily as some growers prune their trees, the object in this case was to thin out the dense growth sufficiently so that sunlight could penetrate easily to all parts of the interior of the tree. Some fairly large cuts were made, especially the first year. This severe pruning treatment was discontinued after four years due to the obviously large reduction in yields. The moderately-pruned trees were cut just enough to remove dead wood, suckers, and watersprouts from the interior of the tree and, in addition, the fruiting area around the outside of the tree was thinned out to some extent. No large cuts were made. The trees in the unpruned block were not cut at all during the six-year period.

Except for the different types of pruning, the trees were all treated alike, receiving the same amount of nitrogen fertilizer and were irrigated in the same manner.

During harvest, the fruit from each individual tree was weighed separately and the entire crop from each of the three plots was graded in a commercial size grader.

Yields, during the six-year period from 1946 to 1951, are given in table 5 and shown in figure 9. At the end of four years, when the severe-pruning treatment was discontinued, the trees which were pruned severely had produced an average of 83 pounds of fruit per tree per year. The moderately-pruned trees produced 111 pounds, while the trees receiving no pruning produced 120 pounds. At the end of six years, the average annual yields for each of these groups were 96, 115, and 122 pounds, respectively.

ENTAL TREES, SEVILLANO VARIETY, CORNING

The approximate amount of wood removed per tree per year is shown

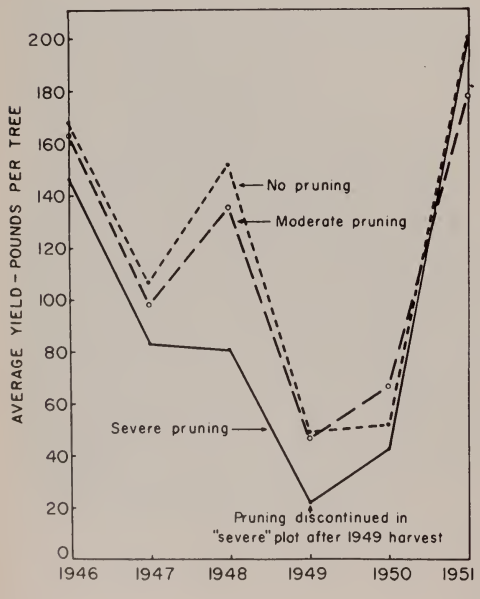
Fig. 7. Tree in the "moderately-pruned" plot.

Fig. 8. Tree in the unpruned plot.

Table 5. Average yield of mature olive trees under three methods of pruning during a six-year period. Corning and Oroville, California.

Year	Severe annual pruning	Moderate annual pruning	No pruning	Difference required for significance	
				at 5 per cent level	at 1 per cent level
	pounds				
Sevillano variety, Corning					
1946	146	163	168		
1947	83	98	107		
1948	81	135	157		
1949	22	47	49		
Four-year average	83	111	120	18	24
1950	43*	67	52		
1951	199*	178	200		
Six-year average	96	115	122		
Mission variety, Oroville					
1946	159	192	202		
1947	14	5	13		
1948	183	204	232		
1949	72	82	120		
Four-year average	107	121	142	32	44
1950	174*	158	187		
1951	126*	145	167		
Six-year average	121	131	154		

* Pruning was discontinued in the severely-pruned plots following the 1949 harvest.



Fruit size, as seen in table 6, increased slightly with severity of pruning. The average size index (see footnote, table 6) of the fruit during the six-year period was 6.654 for the severe pruning, 6.466 for the moderate pruning, and 6.361 for fruit from unpruned trees. Table 7 also shows this trend: 67.3 per cent of the fruits from severely pruned trees were "giant" or above in size, whereas the unpruned trees had 58.3 per cent of their fruits "giant" or above. On the basis of the actual amount of fruit produced per tree, however, over a four-year period the unpruned trees produced 70.3 lbs. of fruit

Fig. 9. Average annual yields of Sevillano olive trees under three pruning treatments during a six-year period. Corning.

"giant" or above in size, moderately pruned trees 62.0 lbs. "giant" or above, and severely pruned trees 55.7 lbs. "giant" or above. Although there was an increase in fruit size on a percentage basis with increased severity of pruning, the decreased yield nullified this benefit.

As shown in table 7, the annual gross income during a four-year period, calculated on an acre basis, was $575.50 for the severely-pruned trees, $717.50 for the moderately-pruned trees, and $826.50 for the trees receiving no pruning. This amounted to a loss of $251 per acre per year for trees severely pruned, and $109 per acre per year for trees moderately pruned. This loss was due primarily to a reduction in yield caused by the removal of fruiting wood.

The values of the fruit in the various size grades as given in table 7 are averages of the prices paid to growers at Corning for Sevillano olives during the years 1946, 1947, 1948, and 1949.

Oroville experiments

This plot was established at the Noel Graves orchard in the Wyandotte area of Butte County, about 7 miles southeast of Oroville. Mission trees, about 35 years old and planted 30 × 30 feet apart, were used. This orchard, on Aiken clay loam soil, produced an average of 1.7 tons of fruit per acre from 1940 to 1949 and has tended strongly toward alternate-bearing. The trees had previously received a light annual pruning for a number of years.

This pruning experiment was established similar to the one at Corning. Three methods of pruning were used—severe, moderate, and no pruning, with ten trees in each treatment. The three plots were situated adjacent to each other with all conditions, other than the type of pruning, being maintained the same. About 65 pounds of prunings were removed per tree each year from the

Table 6. Effect of severity of pruning on fruit size, expressed as size index,* under three methods of pruning during a six-year period.

	Severe pruning	Moderate pruning	No pruning
Sevillano variety, Corning			
1946	6.735	6.670	7.080
1947	6.402	6.328	6.275
1948	6.769	5.852	5.590
1949	7.049	6.987	7.177
1950	7.039	6.750	6.365
1951	5.932	6.206	5.676
Six-year average	6.654	6.466	6.361
Mission variety, Oroville			
1946	1.240	1.235	1.264
1947	3.495	3.118	3.138
1948	1.069	1.079	1.052
1949	2.725	2.650	2.615
1950	1.900	2.210	1.730
1951	2.080	1.490	1.870
Six-year average	2.085	1.964	1.945

* Size index is calculated by multiplying the percentage of fruit in each size grade by the following arbitrary factors, then adding the results. (Standard—0.02, medium—0.03, large—0.04, extra large—0.05, mammoth—0.06, giant—0.07, jumbo—0.08, colossal—0.09, super-colossal—0.10).

Table 7. Effect of three different pruning methods on annual yields, size grades, and gross return over a four-year period. Sevillano olives, Corning, California.

Size grades and value per lb (average of 4 years)	Severe Pruning Yield: 83 lbs per tree (average of 21 trees for 4 years)			Moderate Pruning Yield: 111 lbs per tree (average of 27 trees for 4 years)			No Pruning Yield: 120 lbs per tree (average of 27 trees for 4 years)		
	Per cent in each size grade	Pounds in each size grade	Value, dollars	Per cent in each size grade	Pounds in each size grade	Value, dollars	Per cent in each size grade	Pounds in each size grade	Value, dollars
Super-Colossal (25.3¢)	3.6	3.0	0.76	3.0	3.3	0.83	3.3	4.0	1.01
Colossal (21.9¢)	18.0	14.9	3.26	12.7	12.7	3.09	15.1	18.2	3.99
Jumbo (18.7¢)	25.9	21.4	4.00	23.6	26.1	4.88	22.8	27.5	5.14
Giant (14.9¢)	19.8	16.4	2.44	18.0	19.9	2.96	17.1	20.6	3.07
Mammoth (9.0¢)	11.1	9.2	0.83	17.1	18.9	1.70	15.1	18.2	1.64
Extra Large (6.8¢)	4.9	4.0	0.27	8.1	9.0	0.61	9.3	11.2	0.76
Large (5.1¢)	3.0	2.5	0.13	4.7	5.2	0.27	5.1	6.1	0.31
Medium, Standard, Culls (4.1¢)	13.9	11.5	0.47	12.9	14.3	0.59	12.3	14.8	0.61
			12.16			14.93			16.53
Per cent of fruit "Giant" or above in size	67.3			57.3			58.3		
Pounds of fruit "Giant" or above in size		55.7			62.0			70.3	
Annual pruning cost per tree			.65			.58			.00
Annual gross income per tree			11.51			14.35			16.53
Annual gross income per acre (50 trees per acre)			575.50			717.50			826.50
Reduction in gross income per acre per year due to pruning			251.00			109.00			.....

severely pruned trees and 45 pounds were removed from the moderately pruned trees. The objectives in this experiment were the same as those described for the Corning experiment and the degree of severity of pruning was about the same in both cases. The pruning work was done either during winter or early spring. After four years the severe pruning treatment was discontinued due to obvious reduction in yields.

At harvest, fruit weights were recorded for each individual tree and the size grades of the fruit per plot were obtained by grading a portion of the fruit from each tree through a sample grader of a type that is used at many California olive processing plants.

Yields and size grades were obtained each year for six years. The yields are given in table 5 and figure 10; size-index values are shown in table 6. The severely-pruned trees produced an average of 107 pounds of fruit per tree annually for the first four years. The moderately-pruned trees produced 121 pounds, and trees having no pruning produced 142 pounds. After six years the yields were, respectively, 121, 131, and 154 pounds of fruit per tree annually (see table 5).

As in the Corning plot, the size indexes at Oroville also showed a slight increase in fruit size associated with increased severity of pruning. Little difference in fruit size appeared among the three treatments when expressed as the percentage of fruit of "medium" or larger sizes. Severely pruned trees had 32.3 per cent of the fruit in these size groups, moderately pruned—32.7, and unpruned—32.6. Due to the reduction in total yields, however, with increased severity of pruning, severely pruned trees averaged 34.5 lbs. of fruit of "medium" and larger size, moderately pruned 39.6 lbs., and unpruned 46.2 lbs.

In the Oroville experiment it was again found that yields were reduced according to the severity of pruning and no material benefit was produced in size

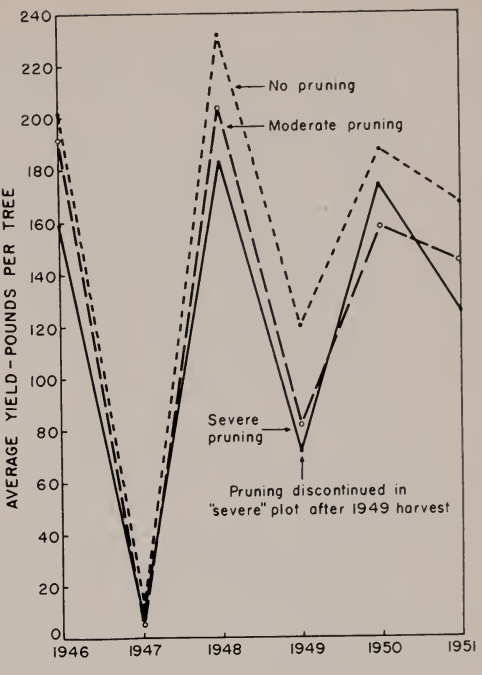


Fig. 10. Average annual yields of Mission olive trees under three pruning treatments during a six-year period. Oroville.

grades. If these results are applied on an acre basis (table 8), the annual gross income per acre with trees severely pruned was $360, as compared to $440.50 for the moderately pruned, and $532 for the nonpruned trees. This resulted in an average annual loss of $172 per acre for severely pruned trees and $91.50 for moderately pruned trees.

The data for the value of the fruit in the various size grades as given in table 8 are averages of the prices paid to growers at Oroville each year from 1946 to 1949.

Tulare County experiments

Five plots were established in Tulare County in 1949 and continued through three seasons. The primary objective in these experiments was to compare yields and fruit quality among heavily pruned, lightly pruned, and unpruned trees. Each of the five plots consisted of 12 trees,

Table 8. Effect of three different pruning methods on annual yields, size grades, and gross return over a four-year period. Mission olives, Oroville, California.

Size grades and value per lb (average of 4 years)	Severe Pruning Yield: 107 lbs per tree (average of 10 trees for 4 years)			Moderate Pruning Yield: 121 lbs per tree (average of 10 trees for 4 years)			No Pruning Yield: 142 lbs per tree (average of 10 trees for 4 years)		
	Per cent in each size grade	Pounds in each size grade	Value, dollars	Per cent in each size grade	Pounds in each size grade	Value, dollars	Per cent in each size grade	Pounds in each size grade	Value, dollars
Extra Large (10.7¢)	1.7	1.8	0.19	1.8	2.2	0.24	1.5	2.1	0.22
Large (10.0¢)	12.8	13.7	1.37	12.9	15.6	1.56	13.2	18.7	1.87
Medium (9.4¢)	17.8	19.0	1.79	18.0	21.8	2.05	17.9	25.4	2.39
Standard (8.4¢)	15.8	16.9	1.42	20.3	24.6	2.07	20.3	28.8	2.42
Sub-standard (5.6¢)	51.9	55.5	3.11	47.0	56.9	3.19	47.1	66.8	3.74
			7.88			9.11			10.64
Per cent of fruit "medium" or above in size	32.3			32.7			32.6		
Pounds of fruit "medium" or above in size		34.5			39.6			46.2	
Annual pruning cost per tree			.68			.30			.00
Annual gross income per tree			7.20			8.81			10.64
Annual gross income per acre (50 trees per acre)			360.00			440.50			532.00
Reduction in gross income per acre per year due to pruning			172.00			91.50			.....

Table 9. Average tree yields during a three-year period for five pruning plots, each receiving heavy, light, and no pruning. Tulare County, California.

Plot No.	Variety	Year	Type of pruning					
			Heavy		Light		None	
			Annual	3 yr average*	Annual	3 yr average*	Annual	3 yr average*
			Pounds					
1	Ascolano	1949	82.2		143.9		162.0	
		1950	180.5		221.8		288.9	
		1951	290.7	184.5	385.4	250.4	376.1	275.7
2	Manzanillo	1949	147.6		200.8		210.6	
		1950	180.0		223.2		291.6	
		1951	245.7	191.1	325.4	249.8	283.5	261.9
3	Mission	1949	27.9		42.3		33.3	
		1950	130.7	79.3	150.9	96.6	305.2	152.6
4	Manzanillo	1949	71.2		92.1		222.3	
		1950	136.0		199.6		105.2	
		1951	220.6	142.6	331.9	207.9	278.4	201.9
5	Sevillano	1949	83.1		97.8		105.1	
		1950	178.3		199.4		145.2	
		1951	298.7	186.7	325.6	207.6	204.3	151.5

* Two-year average for Plot 3.

Table 10. Combined average annual yields per tree and per acre by variety for the five Tulare County plots during the three-year-period—1949 to 1951.

Variety	Type of pruning		
	Heavy	Light	None
	Pounds		
Average yield; pounds per tree per year			
Ascolano	184.5	250.4	275.7
Manzanillo	166.8	228.8	231.9
Mission	79.3	96.6	169.2
Sevillano	186.7	207.6	151.5
Average yield; pounds per acre per year			
Ascolano	6,088	8,263	9,098
Manzanillo	5,504	7,550	7,653
Mission	3,886	4,733	8,291
Sevillano	6,348	7,058	5,151

Table 11. Effect of heavy, light, and no pruning on fruit size at harvest. Tulare County, 1949.

Size grades	Type of pruning		
	Heavy	Light	None
	Per cent		
Ascolano variety			
Colossal	15.1	14.3	4.9
Jumbo	20.3	19.1	25.0
Giant	21.3	20.5	30.8
Mammoth	13.8	13.0	13.4
Sub-standard	29.5	33.1	25.9
Total	100.0	100.0	100.0
*Size index	5.597	5.361	5.660
Manzanillo variety			
Mammoth	6.9	1.9	4.6
Extra Large	10.3	11.0	9.5
Large	25.1	26.0	27.4
Medium	20.8	24.3	16.9
Standard	25.8	25.9	22.2
Sub-standard	11.1	10.9	19.4
Total	100.0	100.0	100.0
*Size index	3.184	3.060	2.992

* Size index calculated as described in Table 6.

four pruned by each of the three methods used. Mature trees, 35 to 40 years old, in irrigated orchards were used. Two plots were of the Manzanillo variety, one of Ascolano, one Mission, and one Sevillano.

All the trees were large and brushy at the start of the experiments. Pruning techniques in all the plots were essentially the same. During the first year the heavy pruning consisted of drastic heading back to large lateral limbs about 16 feet above ground by means of saw cuts on the upright main branches. Some dead brush and weak twigs were clipped out. Up to one half of the total top growth was removed. Light pruning amounted to a general thinning out of the weaker wood, using smaller saw cuts. Some heading back to improve light conditions and facilitate harvesting by center limb removal, was also undertaken. Not more than one sixth of the top was eliminated.

In the second year of heavy pruning there was some light saw work to shorten excessively widespreading laterals. Considerable clipper cutting was used to thin the suckers. About one third of the top was removed. The lightly pruned trees received some light saw cutting to further eliminate weak undergrowth and undesirable laterals. Not more than one seventh of the top was removed.

In the third and last year the heavily-pruned trees were suckered by means of saw and shears. All remaining old wood —twigs and laterals up to two inches in diameter—were removed, leaving the tree with no fruiting wood over three years old. About one fourth of the top was removed. The lightly pruned trees were again gone over lightly with the saw and shears, removing not more than one eighth of the top.

Yield records were obtained for each tree in each plot during the 1949, 1950, and 1951 harvests. This data is given in table 9. Table 10 shows the combined average yields of the five plots by variety, both on a per-tree basis and on a per-acre basis for the three types of pruning.

The possible effect of the three types of pruning on fruit size was obtained by size-grade determinations on two of the plots in 1949. This data is given in table 11.

In agreement with earlier studies, the Tulare County experiments showed that the immediate effect of pruning large, mature olive trees is to reduce the crops in proportion to the amount of pruning done. This held true for each plot, except no. 4 (Manzanillo) where the lightly pruned trees yielded about the same as the unpruned trees, and no. 5 (Sevillano) where the lightly pruned trees outyielded both the heavily pruned and the unpruned trees.

In the two instances where the effect of pruning on fruit size was studied, in one (Ascolano), fruit size was essentially the same regardless of pruning method, while in the other (Manzanillo) there was a slight, but consistent, increase in fruit size associated with the increased amount of pruning. This is probably a reflection of the reduced amount of crop on the heavier pruned trees.

DISCUSSION

These three series of experiments were designed to secure information as to the effect of severity of pruning bearing olive trees on yields and size grades over a period of years. The results in each case are in agreement with the earlier work of Merrill and Condit (1928) and of Moore (1945) in establishing the fundamental fact that reduced yields are associated with an increased severity of pruning. In addition, it is evident that fruit size is not markedly affected by pruning—at least on trees grown under irrigation. This finding may or may not apply to trees receiving no irrigation.

It would seem reasonable to conclude from these experiments that in pruning bearing olive trees, the pruning should generally be moderate and for some definite purpose. It should be the lightest type which can be done and still accomplish its purpose. In other words, when an excessive amount of fruiting wood is removed from bearing olive trees, the result is a reduction of the crop.

It has been noted in a number of instances, that following a severe pruning, olive trees set a heavier crop than trees which were not pruned so heavily. This same effect has been observed in cases where trees were top-worked during the early spring and one or two nurse branches were left. These nurse branches usually set a heavy crop. This is probably due to the decreased top-root ratio, which provides the remaining top portion of the tree with a greatly increased nutrient and water supply from the undisturbed root system. This situation has led to a belief that heavy pruning is an effective method of inducing the trees to set heavy crops. While the remaining branches after a heavy pruning often have a better set of fruit per unit branch length than on comparable unpruned trees, it must be remembered that a large amount of the bearing surface has been removed. If total yields per tree are compared over a period of years, the results are likely to be in favor of the lightly pruned tree.

Also, such heavy pruning to increase fruit set could not be done every year.

The question arises frequently as to whether pruning can be used effectively in overcoming alternate-bearing in olives. The Graves orchard at Oroville is a good example of olive trees in an alternate-bearing condition. Table 5 and figure 10 show that the alternate-bearing was equally prominent under all three of the pruning methods used during the six years records were taken. In other words, the severity of pruning did not affect the alternate-bearing tendency, at least when the pruning was done annually.

It must not be concluded from this study, however, that no pruning of bearing olives is to be recommended. A certain amount of pruning is undoubtedly necessary and can often be justifiably done without appreciably reducing the tree's fruit-bearing area and subsequent yields. The required pruning depends, of course, upon the condition of the trees. Old, neglected trees, containing much dead wood and interfering branches would obviously need more pruning than trees properly trained from the beginning, with well-placed scaffold branches. While fairly heavy pruning may be necessary for one or two years to remove dead and interfering branches from neglected trees, a fairly light type of pruning may be sufficient after that.

Reasons for pruning bearing olive trees

1. Removal of suckers and watersprout growth. Except where growing into open, unshaded parts of the tree, wood of this type contributes nothing to the tree's production and can be pruned out without reducing yields. Its removal

Fig. 11. Top: Dense growth of nonfruitful suckers and watersprouts around the base of the tree. Bottom: The same after removal of excess wood. No fruiting wood was removed but harvesting and spraying is greatly facilitated.

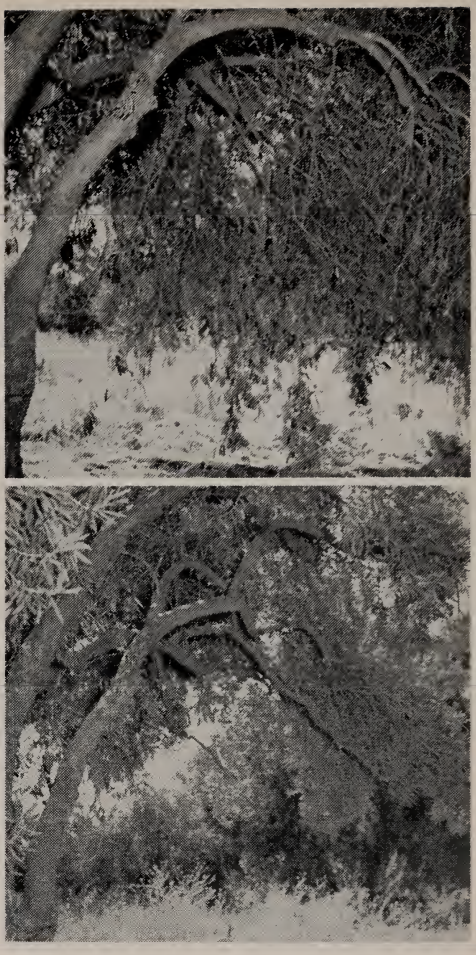


Fig. 12. Top: Large area of dead, brushy growth on the lower side of a branch. Bottom: The same after removal of the dead wood. No fruit-bearing wood was taken off. This type of pruning needs to be done once in two or three years.

will facilitate harvesting the fruit in the inner portions of the tree.

Taking out such unnecessary wood will reduce the likelihood of development of peacock spot (*Cycloconium oleaginum*) and the various scale insects. If sprays are necessary to control such pests, the previous removal of this wood will allow better spray penetration.

An example of such excess wood that can justifiably be removed is shown in figure 11—before and after. Pruning of this type should be done each year.

2. Removal of dead wood and thinning out dense, brushy growth in the fruiting areas. Branches such as shown in figure 12 often have many dead twigs which should be removed. This type of pruning is time consuming, but it will aid in the control of disease and insect pests. Care should be taken not to remove any of the healthy, fruit-producing wood on the upper or outside portions of these branches.

Fig. 13. Left: Too many scaffold branches have been allowed to develop giving an overcrowded condition throughout the tree. Right: The same tree after removal of some of the excess branches. Several more could be removed a year or two later.

3. Removal of excess primary scaffold branches. In some cases too many large scaffold branches have been retained from the beginning, and an over-crowded condition is found throughout the tree (figure 13). A number of the large branches may go up to great heights without branching and may be bearing only a few tufts of fruiting branches in the top of the tree. A judicious removal of several of such branches often results in a much better distribution of the fruit-bearing surface and will greatly facilitate harvesting. Pruning of this type only needs be done once provided new watersprout growth is not allowed to develop into large, badly-placed branches. Such a heavy, renovation-type of pruning is sometimes best done over a two- or three-year period.

Care must be taken, however, not to go to the other extreme and remove too many of the large central branches. Instances are quite common where the tops or centers of well-balanced trees are completely removed, or opened up, to let the sunlight in, presumably in an attempt to cause fruit production inside of the tree. It is unlikely that the inner portion of an olive tree can ever be made to bear much fruit. The natural fruit-producing area of the olive consists of a hemispherical shell as shown diagrammatically in figure 14. Best results are likely to be obtained if this fruit-bearing shell is retained and kept in a healthy growing condition.

Removing the central portion of the tree and exposing the bark of the trunk and the large primary scaffold branches to the direct rays of the sun can result in considerable injury, unless whitewashing is promptly done.

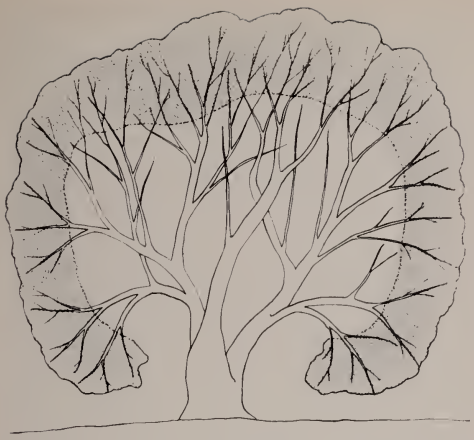


Fig. 14. The natural fruit-bearing area of the olive tree is a hemispherical shell. Highest yields are likely if this outside area is kept as large as possible, reaching as close to the ground as cultivation implements permit.

4. Heading back of the upright and lateral branches. This applies to mature trees that have surpassed a height which is considered to be the maximum that can be economically harvested. If allowed to grow unchecked, especially in fertile soils with irrigation and nitrogen fertilizer applications, olive trees of some varieties will eventually reach such heights that harvesting becomes impossible except by knocking the fruits off with poles or cutting off the topmost branches and then removing the fruit. Trees in such a condition may have to be drastically cut back as shown in figure 15, but for a period of two to four years there will be a substantial reduction in crop until the watersprouts resulting from such pruning again become fruiting wood. Much judicious subsequent pruning is necessary to prevent overcrowding of the watersprout growth. A better procedure would be to prevent the trees from reaching such undesirable heights by an annual or biennial heading back of the upright growing branches. This applies in particular to varieties such as the Mission which have a naturally tall, upright growth habit.

It may also be necessary to continually cut back the lateral branches after a tree has occupied all the area which can be allotted to it. This is particularly important with closely planted trees. If they are allowed to spread out to such an extent that no sunlight can penetrate between the trees, the entire bearing area is eventually found only in the tops of

Fig 15. Left: Mission olive trees about 80 years old and approximately 50 feet high. Hand picking of fruits in the tops of such trees would obviously be impractical. Right: The same trees after a drastic heading back. Fruit production will be curtailed until new fruiting wood has developed.

Fig. 16. A dense, closely planted orchard. The trees are set 20 x 20 feet apart. Little can be done by pruning to remedy such a situation. The best solution is to remove some of the trees.

the trees. This limits the bearing surface per tree considerably and, in addition, makes harvesting very difficult.

In figure 16 an orchard is shown in which the trees are planted very closely together—20 by 20 feet; trees so situated cannot be helped much by pruning. Under such conditions a program of partial tree removal should be considered.

Time of pruning bearing olive trees

The pruning of bearing trees in good structural condition, being limited to the removal of dead wood, suckers, watersprout growth, and an occasional thinning out and heading back of branches, can be done at any time during the year when it will fit in best with the other cultural practices. In orchards infected with olive knot (*Bacterium savastanoi*) it is best to prune only in the dry season, to reduce the possibility of rain spreading the bacteria into the fresh pruning wounds and starting new points of infection. In such orchards the use of a Bordeaux mixture-grafting wax paste is useful in covering pruning wounds to prevent the start of new infection areas.

Mechanical pruning

In an effort to reduce pruning costs some olive growers have experimented with tree hedging and topping machines (figures 17, 18, 19). Although not fully evaluated, observations following two seasons of use in Tulare County indicate certain advantages and disadvantages of this practice.

Advantages

Speed. Several acres can be given a rough machine pruning in one day.

Fig. 17. Mechanical pruner topping large olive trees.

Fig. 18. Removing brush from trees following topping.

Reduced cost. This varies according to size and density of the planting but averages 30¢ to 80¢ per tree, compared to $1 to $3 per tree for hand pruning.

Uniform pattern. Trees can be trimmed to a predetermined size and shape.

Disadvantages

Follow-up removal by hand. For safety to pickers and to preclude entrance of disease organisms, particularly heart rot fungi and olive knot bacteria, snags and broken limbs require subsequent removal. This work may be largely accomplished by use of a hand-operated circular or chain power saw.

Hedging machines break off low limbs that impede the forward movement of the equipment. Interlacing trees had best be trimmed with manually-operated power saws prior to machine hedging.

Machines are not selective. Some desirable productive wood will be cut off.

Regardless of methods used, inside dead wood and weak unproductive limbs require selective hand removal. Following hedging or topping, a large number of watersprouts develop. Many of these weaken and die because of crowding and shading and probably would require some hand thinning.

CONCLUSIONS

1. When bearing olive trees are pruned, yields are reduced in proportion to the amount of fruit-bearing wood which is removed.

2. Severe pruning does not result in an increase in fruit size sufficient to offset the reduced yields.

3. Bearing olive trees need to be pruned, but such pruning may best be considered as a "necessary evil." All cutting should have some definite objective. Some of these objectives are:

Fig. 19. Manzanillo trees one year after mechanical topping.

To make harvesting and spraying easier, and to reduce the amount of infection by disease and insect pests:

Remove dead wood, suckers, and watersprouts.

Thin out dense, brushy growth in the fruiting area.

Remove an excess number of scaffold branches where such conditions occur.

To keep the trees down to reasonable heights and to keep them within the growing area available:

Head back the upright and lateral branches annually.

Drastically head back large limbs where trees have grown to impractical harvesting heights. A substantial loss of crop must be expected for two to four years when this is done.

4. Pruning of olive trees can be done at any time during the year but in orchards infected with olive knot it is best done in summer to reduce the spreading of the bacteria.

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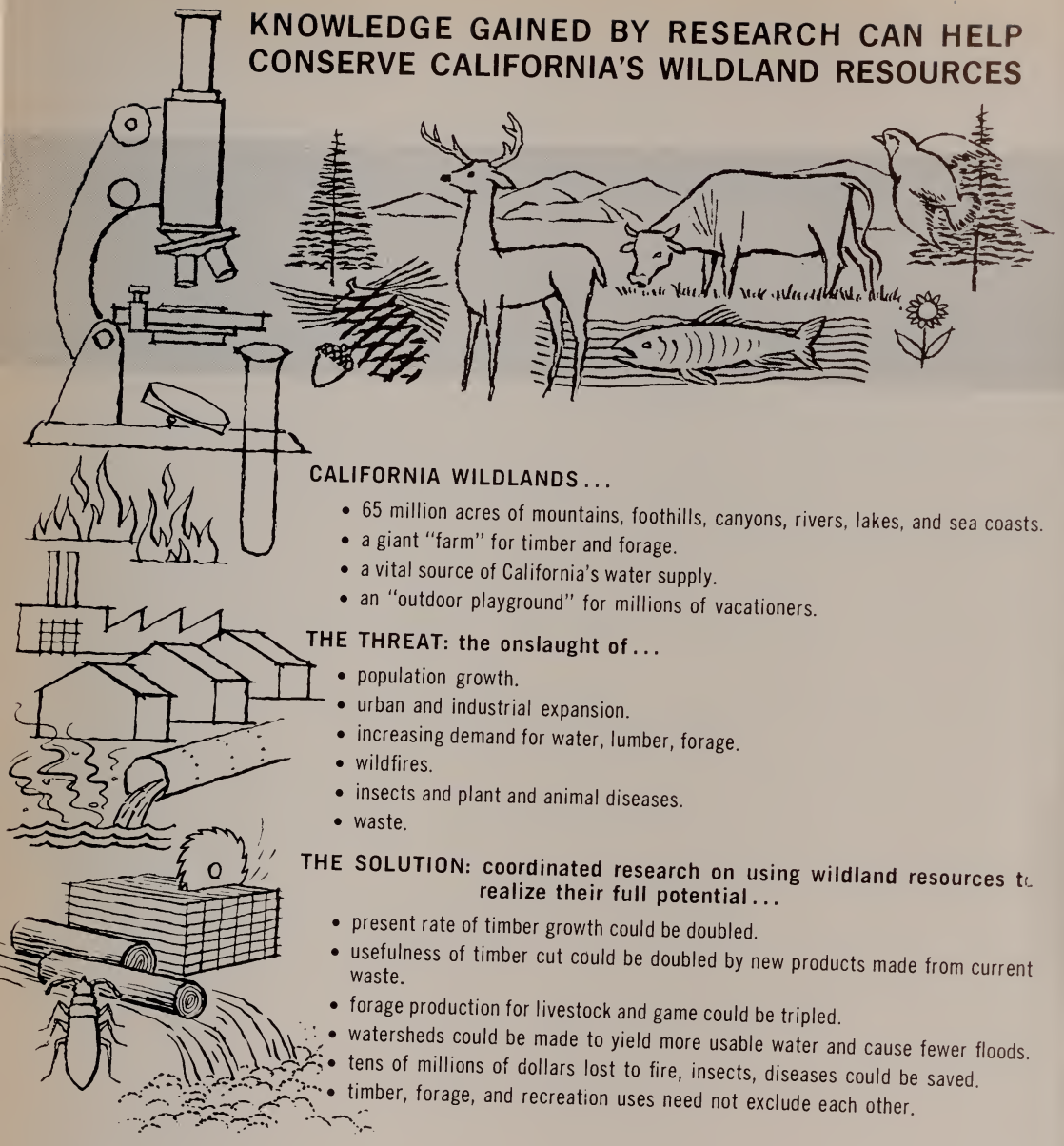
KNOWLEDGE GAINED BY RESEARCH CAN HELP CONSERVE CALIFORNIA'S WILDLAND RESOURCES



CALIFORNIA WILDLANDS...

- 65 million acres of mountains, foothills, canyons, rivers, lakes, and sea coasts.
- a giant "farm" for timber and forage.
- a vital source of California's water supply.
- an "outdoor playground" for millions of vacationers.

THE THREAT: the onslaught of...

- population growth.
- urban and industrial expansion.
- increasing demand for water, lumber, forage.
- wildfires.
- insects and plant and animal diseases.
- waste.

THE SOLUTION: coordinated research on using wildland resources to realize their full potential...

- present rate of timber growth could be doubled.
- usefulness of timber cut could be doubled by new products made from current waste.
- forage production for livestock and game could be tripled.
- watersheds could be made to yield more usable water and cause fewer floods.
- tens of millions of dollars lost to fire, insects, diseases could be saved.
- timber, forage, and recreation uses need not exclude each other.

THE WILDLAND RESEARCH CENTER at the University of California was established to help conserve California wildland resources through research. It operates within the University's state-wide Agricultural Experiment Station, with administrative headquarters on the Berkeley Campus.

THE CENTER...

- coordinates and supports research in more than a dozen fields.
- integrates studies of complex wildland problems.
- strengthens cooperation between University and other research workers.
- promotes the exchange of information between research workers and wildland managers and policy makers.
- collects and disseminates scientific data on wildland studies.

TO KNOW IS TO LIVE IN ABUNDANCE...